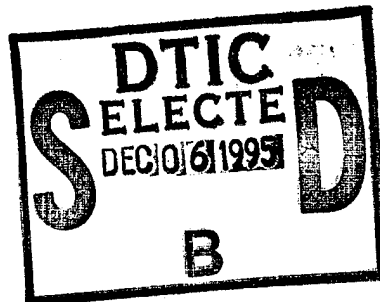


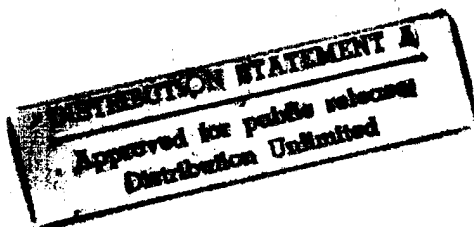
Logistics Management Institute

National Aeronautics and Space Administration Guidance for Improving Customer Satisfaction

NS302RD1



Lawrence Schwartz
Brian E. Mansir



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National Aeronautics and Space Administration
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PREFACE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION GUIDANCE FOR IMPROVING CUSTOMER SATISFACTION

NASA is required to meet the requirements of the President's Executive Order 12862, *Setting Customer Service Standards*. The Headquarters steering group is developing a plan to meet those requirements. The approach requires that each of NASA's Strategic Enterprise Units develop its own customer service plans, take a satisfaction survey of major external customers (in the next six months), and target areas for improvement. A NASA agency progress report is due to the President by 8 September 1994.

The Logistics Management Institute (LMI) has been engaged to provide a common approach for planning, conducting, and analyzing customer satisfaction surveys. LMI has also been asked to develop a performance measurement framework for consistently undertaking and gauging improvement initiatives. In this way, NASA will be in a position to consolidate individual customer service plans into an agency plan.

LMI will be available to the Strategic Enterprise Units for advice and guidance in accomplishing these improvement initiatives. The authors can be reached at telephone number (301) 320-2000 for such assistance.

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EXECUTIVE SUMMARY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GUIDANCE FOR IMPROVING CUSTOMER SATISFACTION

Executive Order 12862, *Setting Customer Service Standards*, requires that NASA undertake customer satisfaction surveys to obtain customer feedback for improving its products and services. It also requires NASA to search for best industry methods and incorporate them into current practices as appropriate. Executive Order 12862, however, does not provide much in the way of guidelines for its implementation.

This paper provides a comprehensive set of guidelines for complying with the provisions of Executive Order 12862. The guidance is presented as follows:

Section 1: Introduces the requirements of Executive Order 12862 and shows the relationship of those requirements to other NASA improvement efforts.

Section 2: Outlines NASA's Strategic Enterprise Units and their customers. It also defines an appropriate level of process aggregation for the Strategic Enterprise Units to design customer satisfaction surveys that can directly lead to performance improvements for NASA.

Section 3: Delineates a quality measurement framework to guide the focus of customer satisfaction surveys. It also provides practical advice on planning, conducting, and analyzing the customer surveys as well as a basis for prioritizing performance improvement initiatives.

Section 4: Offers a total performance measurement framework--combining cost, output, and quality--to further guide the accomplishment of industry benchmarking, continual improvement, and implementation of the Performance and Results Act of 1993. It uses a NASA case study to demonstrate the utility of this performance measurement framework.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GUIDANCE FOR IMPROVING CUSTOMER SATISFACTION

1. INTRODUCTION

IMPROVEMENT EFFORTS

During the spring of 1992, the National Aeronautics and Space Administration (NASA) embarked on a continual improvement program to enhance customer satisfaction with its products and services. NASA's continual improvement effort, which focuses both on reducing costs and increasing quality, uses a traditional five-element improvement cycle. Figure 1-1 illustrates NASA's improvement cycle.

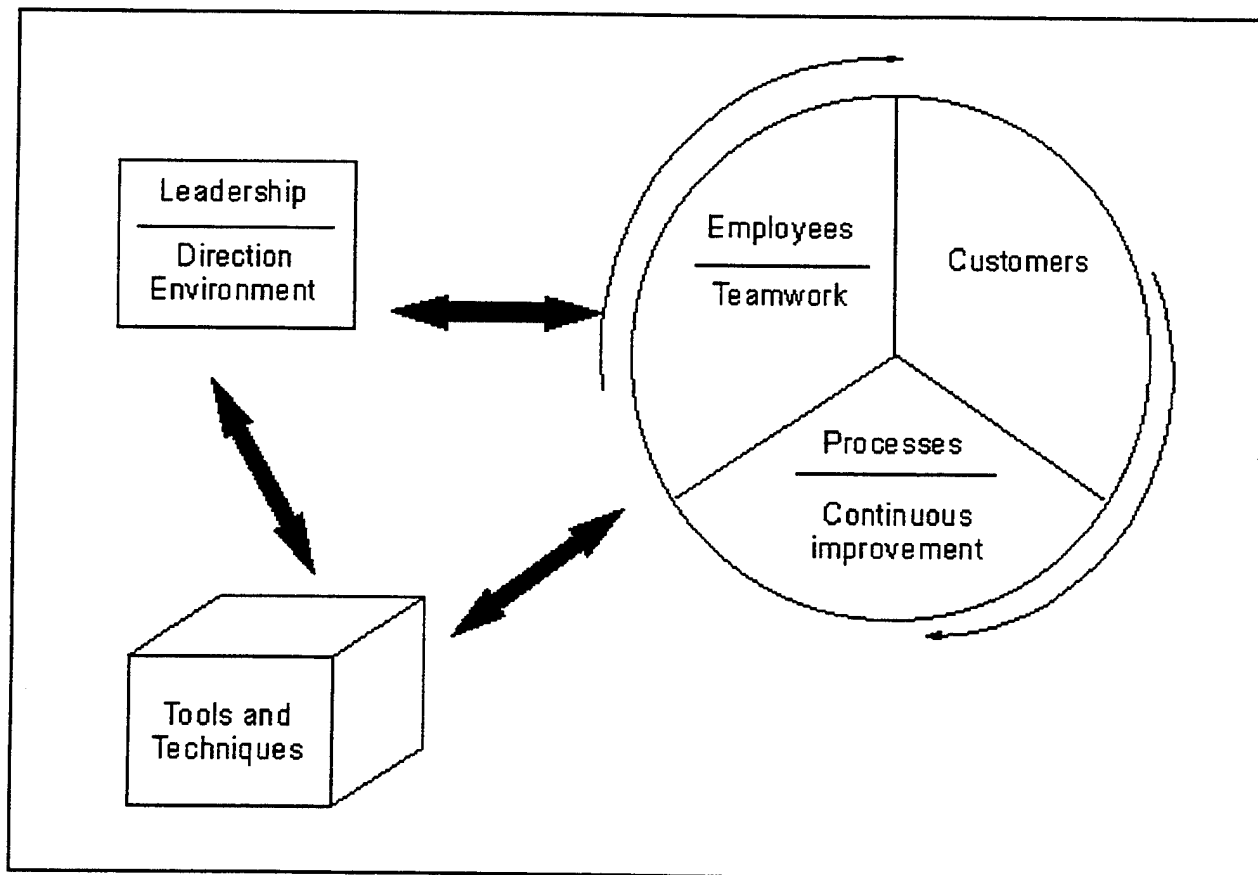


FIGURE 1-1. NASA's Improvement Cycle

The five elements of NASA's improvement cycle are:

- (1) Customers judge the results (through the use of advisory groups and formal surveys)
- (2) Process definition provides the understanding for addressing customer concerns
- (3) Management and employee groups (the stakeholders) work in teams to improve processes
- (4) Leadership gives focus, alignment, and direction to team efforts
- (5) Tools and techniques are used to bring about process improvement; they include cross-functional problem solving, controlled testing, and performance measurement.

Like other Government agencies, NASA is required to pursue two related improvement initiatives. First, in September 1993, the President issued Executive Order 12862, *Setting Customer Service Standards*, to help implement the recommendations of the National Performance Review. Executive Order 12862, as with NASA's continual improvement effort, focuses on reducing costs and increasing product/service quality to improve customer satisfaction. However, the Executive order places special emphasis on taking formal surveys to obtain customer feedback and on benchmarking related industry practices to improve Government processes. Government agencies are to begin those activities in FY94.

Second, the Performance and Results Act of 1993 requires NASA not only to improve costs and enhance quality, but also to focus on outputs and performance budgeting. It further requires pilot tests to develop strategic plans, to construct operating plans, and to formulate performance budgets (in terms of outputs, quality, and costs). The pilot tests are to be completed by September 1997, with a full performance budgeting system in operation by the year 2000.

We believe that all of these efforts--continual improvement, Executive Order 12862, and the Performance and Results Act of 1993--should be thought of as integral to an overall performance improvement system. Certainly, the five-stage continual improvement cycle is needed to make the other two efforts effective. Also, a cohesive performance measurement system provides the capability to focus on all aspects of performance (cost, quality, and output), coordinate improvement efforts, and gauge the results.

EXECUTIVE ORDER 12862

Executive Order 12862 requires that NASA take customer satisfaction surveys to obtain customer feedback for improving its

products and services. It also requires NASA to search for best industry methods and incorporate them into current practices as appropriate. The Executive order, however, does not provide much in the way of guidelines for its implementation.

NASA needs a comprehensive set of guidelines for complying with the general provisions of Executive Order 12862. This guidance answers the following questions:

- (a) Who are NASA's general customers?
- (b) Who in the NASA organization should be taking customer satisfaction surveys and searching for best industry models?
- (c) What should NASA measure to obtain meaningful customer feedback and relevant industry information for improving performance?
- (d) How should NASA approach customer satisfaction surveys?
- (e) When should NASA undertake customer satisfaction surveys and search for best industry practices?

ORGANIZATION OF PAPER

This guidance presents a strategy for NASA to meet the requirements of Executive Order 12862, to further its continual improvement efforts, and to prepare for the challenges of the Performance and Results Act of 1993.

Section 2 discusses NASA's customers and organizational structure, and the concept of a process for diagnosing problems and making process improvements.

Section 3 focuses on meeting the requirements of Executive Order 12862. It defines a measurement framework for assessing customer satisfaction and outlines the basic steps for planning, conducting, and analyzing customer satisfaction surveys.

Section 4 presents a more complete performance measurement system. It contains the measurement framework for assessing customer satisfaction discussed in the previous section, and other performance measures that are needed to meet the industry benchmarking requirements of Executive Order 12862, continual improvement efforts, and the Performance and Results Act of 1993.

2. DEFINITION OF A PROCESS

Everything NASA does involves a process. Every process includes one or more inputs (facilities, management, and research staff); a variety of transformations; and various outputs and levels of quality. Figure 2-1 illustrates the most simple process, with customer and supplier feedback.

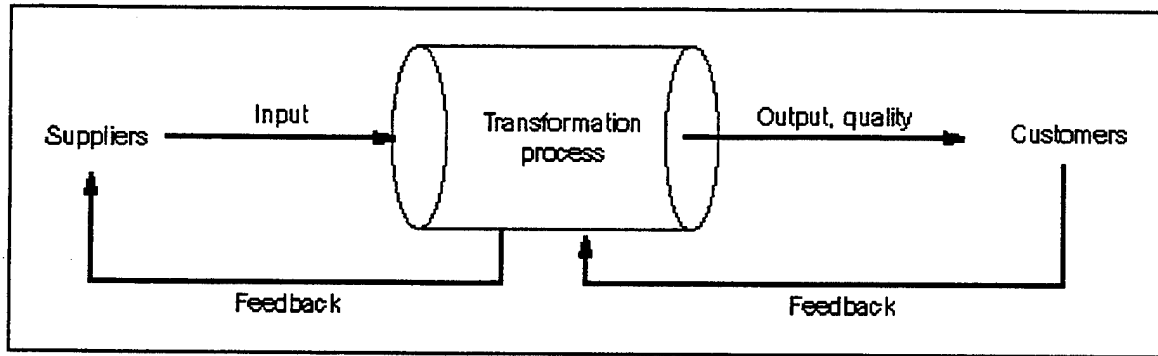


FIGURE 2-1. A SIMPLE PROCESS

CUSTOMERS

NASA is currently undertaking an input/output analysis to fully identify its customers, products and services, inputs, suppliers, and associated processes. In broad terms, that analysis has shown that NASA's external customers are the science and education communities, the aerospace industry, the aeronautics and aviation industries, and other government agencies. Five Strategic Enterprise Units (SEUs) have been defined to focus on strategic objectives and external customers.

NASA's five SEUs are Mission to Planet Earth, Aeronautics, Human Exploration and Development of Space, Scientific Research, and Space Technology. The SEUs differ in their customer focus. For example, the Aeronautics Enterprise serves the aeronautics industry and other U.S. government agencies, while the Space Technology Enterprise serves the aerospace industry. However, some SEUs serve some of the same external customers. For example, although many of the external customers of the Mission to Planet Earth Enterprise and the Scientific Research Enterprise differ substantially, they both serve the science community in various ways. Also, some of the customers are general rather than specific, such as customers of public affairs or publications.

NASA headquarters has indicated that each SEU will be responsible for developing a customer service plan to meet the requirements of Executive Order 12862. Each SEU should plan and conduct at least one customer survey during the next six months. We

now address the appropriate process aggregation level for SEUs to undertake customer satisfaction surveys and other performance initiatives.

PROVIDERS

NASA needs to define the appropriate organizational level in its organization for defining its processes and for meeting the requirements of Executive Order 12862 and other performance improvement initiatives. We believe that NASA should not define its processes too broadly or too narrowly to effectively undertake performance improvement.

In principle, we should consider at least four levels of aggregation for defining NASA's processes. First, NASA could consider each of its five SEUs as a separate process. Second, at a somewhat more detailed level, NASA could consider each of its 12 current budget programs (e.g., Launch Services, or Physics and Astronomy) as individual processes. Third, at a still more disaggregated level, NASA could define separate processes for the specific products/services it provides at each of its nine research centers or at its Headquarters. (As an example, one process could consist of all wind tunnels at Ames Research Center). Fourth, at an even more detailed level, NASA could define separate processes for each of its functional areas, such as maintenance and repair of buildings, facilities, and structures.

NASA needs some criteria to select the most appropriate definition of process aggregation for undertaking performance improvement initiatives. We believe that four criteria have application to NASA. A process should do the following:

(1) Encompass products/services that are produced jointly through the use of common staff, equipment, facilities, and technology. In economics, this criterion would be referred to as the production function.

(2) Come under the control of a manager who is directly responsible and accountable for strengthening operations and improving customer satisfaction related to certain products/services. For NASA, this criterion means that each process needs to be defined in terms of the relevant research center and headquarters SEU that oversees its operation.

(3) Serve as a diagnostic tool for taking action if specific performance improvements are warranted by customer feedback. This criterion means that the process is keyed to the products/services provided to specific customers, and the process is detailed enough to pinpoint actionable items.

(4) Point to areas in which industry best practices might be useful for making improvements. NASA should be able to identify specific functions (or a group of functions) from its processes, search for industry methods that relate to those functions, and incorporate the best industry practices into its processes. In the continual improvement literature, this practice is referred to as "benchmarking."¹

We now apply these criteria to select the most appropriate level of aggregation for defining NASA processes.

Table 2-1 shows a matrix of the four alternative process aggregation levels (the rows) and the four selection criteria (the columns). We indicate a "yes" in the cells when the process aggregation levels satisfy the specific criteria for process aggregation and "no" when they do not.

At one extreme, the matrix shows that defining processes at the strategic enterprise unit level is too broad for undertaking performance improvements. At the other extreme, defining processes at the functional level is too narrow to diagnose all potential customer concerns in a specific product or service. As Table 2-1 shows, all four criteria are satisfied only for the products/services at each of NASA's research centers or at headquarters. It is at this level of process aggregation that performance improvement initiatives align with the managers who directly diagnose performance problems, consider the best practices of industry, and make process improvements.

We conclude that NASA should define its processes along product or service lines at each of the nine research centers or at headquarters. For example, the Ames, Lewis, and Langley Research Centers all operate and manage wind tunnels for both NASA and industry customers. Nonetheless, a separate wind-tunnel process should be defined for each of the three research centers. If this is done, the three separate wind-tunnel processes would reflect the differences in their operations, thereby fostering customer feedback, industry benchmarking, and improvement initiatives. The Aeronautics Enterprise would aggregate and report on wind-tunnel processes and other processes that fall under its purview.

¹See Robert C. Camp, *Benchmarking: The Search for Industry Best Practices that Lead to Superior Performance*, White Plains New York: Quality Resources, 1989, for an in-depth treatment of benchmarking.

Table 2-1

SELECTION OF PROCESS DEFINITION

Process aggregation Level	Criteria for selection			
	Production function	Direct manager control	Diagnostics for improving customer satisfaction	Industry benchmarking
Strategic enterprise unit	Yes	No	No	No
Budget program	Yes	No	No	No
Products/services at research centers or headquarters	Yes	Yes	Yes	Yes
Function	Yes	Yes	No	Yes

3. EXECUTIVE ORDER 12862

Executive Order 12862 requires NASA to develop customer satisfaction surveys and performance industry benchmarking in order to improve its operations. We believe that NASA should first focus on taking customer satisfaction surveys (for at least a year) before undertaking industry benchmarking. This will give NASA an opportunity to understand its customer standards well, a necessary first step before considering the introduction of best industry standards.

Also, industry benchmarking requires not only a focus on quality--as is the case for customer satisfaction surveys--but also on cost and output performance. NASA will have to develop cost and output measures before it can properly undertake industry benchmarking. Section 4 provides the broader measurement system that NASA will need to comply with the industry benchmarking requirements of the Executive Order (and with continual improvement and the Performance and Results Act).

Presented below is the quality measurement approach needed for meeting the customer survey requirements of the Executive order. It is followed by guidance for planning, conducting, and analyzing customer surveys.

QUALITY MEASUREMENT

Executive Order 12862 basically requires that the customer survey effort provide data for determining status of quality in NASA products/services, for prioritizing NASA improvement initiatives, and for gauging overall progress.

The Executive order requires that the customer survey instrument cover the following four areas:

- (a) Customer standards for each quality dimension of a product/service
- (b) Customer satisfaction levels for every product/service quality dimension
- (c) Customer importance attached to each product/service quality dimension
- (d) Customer concern with product/service expenditures

Surveys need to be structured so that the respondents register their feelings in quantitative terms. Such scoring should be done for each of customer standards, satisfaction levels, importance levels, and expenditure concerns. The resultant data then can be combined to meet Executive Order 12862 requirements.

Equation 3-1 shows how to combine much of the data into a quality index. In accordance with our definition of process, the quality index represents "n" quality factors of a product/service that is produced by a research center or by headquarters for a certain set of customers. Scores on actual and standard levels are compared and then weighted by relative customer importance scores. (These scores are obtained through the customer survey as explained later in this section.)

$$\begin{aligned}
 \text{QI} = & w(1) \times [\text{actual quality}(1) / \text{standard quality}(1)] + & [\text{Eq. 3-1}] \\
 & w(2) \times [\text{actual quality}(2) / \text{standard quality}(2)] + \dots + \\
 & w(n) \times [\text{actual quality}(n) / \text{standard quality}(n)]
 \end{aligned}$$

Equation 3-1 is a useful tool for determining the quality factors most in need of improvement. As an example, if two quality factors achieve only 40 percent of their standard levels, then the one with the greater customer weight should receive the highest priority for making improvements. In contrast, a quality factor with an 80 percent achievement level relative to its standard (and a relatively low customer weight) should receive a lower priority for implementing improvements. Moreover, these quality shortfalls also should be compared with customer expenditure concerns for the product/service. It is possible that customer expenditure concerns are as great as or greater than any particular quality shortfall, and that should be taken into account before prioritizing NASA improvement efforts. See Section 4 for a more complete discussion of customer expenditure concerns and NASA costs for producing products/services.

The quality index is also a useful tool for measuring the degree to which overall quality standards are met. For example, a 70 percent quality index score would mean that, on the average, the process is achieving 70 percent of the quality standards desired by the customers. The maximum quality index score is 100 percent and the minimum is 0 percent.

CUSTOMER SURVEY

There are three phases for undertaking customer surveys: planning for the survey, conducting the survey, and analyzing its results.

Survey Plan

The design of a survey includes identifying NASA's customers, structuring the questionnaire, and planning for sampling the customers. All of these considerations are important for ensuring that NASA obtains accurate and unbiased feedback from its customers.

NASA is already defining its customer base in precise terms. This is an important first step toward meeting the requirements of Executive Order 12862.

The customer questionnaire should be developed using a working group for each process. For example, a working group could be formed for the wind-tunnel process at the Ames Research Center. This group could include the manager of the process, selected members of the manager's staff, a key customer, and a survey expert. The manager and staff would ensure that customer feedback is meaningful for making improvements to their process. The customer participant would increase the likelihood that important product/service characteristics are included in the questionnaire, while the survey expert would help the group to avoid unclear and biased wording in the questionnaire.

Survey research has shown that a mail questionnaire needs to follow a certain structure to obtain an acceptable response rate. First, it should include a cover letter describing the survey's importance. The cover letter should include the following: NASA intends to take periodic surveys to determine how well it is meeting the needs of its customers; customer feedback will help NASA make improvements to its processes; customer cooperation is essential for continually improving NASA's products/services; and NASA guarantees that individual respondent data will be kept confidential.

Second, the survey questions should be written in sections: one section on customer satisfaction levels, another on customer standards, still another on customer expenditure concerns, and finally one on the importance that customers attach to specific product/service characteristics. The questions should be structured so that respondents can express their feelings in degrees of intensity. Survey research further shows that use of a 7-point scale, with appropriate descriptive labels, is very effective. Using the example of the Ames Research wind tunnel, a survey question on customer satisfaction levels could be as follows:

How satisfied are you with the reliability of wind-tunnel services provided by the Ames Research Center:

- 1-Not satisfied?
- 2-Slightly satisfied?
- 3-Somewhat satisfied?
- 4-Fairly satisfied?
- 5-Quite satisfied?
- 6-Very satisfied?
- 7-Extremely satisfied?

All sections should conclude with a question that elicits customer explanations for relatively negative answers (such as 1,2, or 3 in the above sample question) or general comments.

After the questionnaire sections, the survey should conclude with two additional types of questions. One should address the customers' overall rating of NASA's products/services, again using a 1-to-7 scoring scale. Such a question is useful for checking the consistency of customer responses throughout the questionnaire. The other question should be aimed at developing a business profile of the customer. That information should be useful in determining whether different types of customers have similar feelings about various aspects of NASA's products/services, which may help NASA target its products/services to specific customers.

Before conducting the survey, each working group should pre-test the questionnaire to check for possible bias and ensure that the questions are clear and effective. The pretesting should result in the elimination of long, awkwardly worded, or ambiguous questions; redundant questions; and wording that may offend or sound foolish to respondents. Questionnaires are routinely improved when pretested.

A mail survey, by itself, is often not sufficient for obtaining an adequate survey response rate. The Office of Management and Budget requires that Government customer satisfaction surveys strive for a 75 percent response rate. Survey research shows that a mail survey often achieves only a 40 percent response rate. To increase that response rate, organizations need to take two additional actions--a reminder card and a follow-up with a telephone call or in-person interview. These steps -- a mail survey, followed by a card and telephone/in-person interview -- are referred to as the "total design method" in survey research circles.

Table 3-1 compares the various survey methods and illustrates that the total design method often achieves acceptable response rates at reasonable costs.² A questionnaire generally costs about \$5.00 for handling and mailing. However, because only 40 percent are returned, the cost of the initial and follow-up mail questionnaires increases to approximately \$12.00 ($\$5/0.40$) in order to obtain satisfactory response rates. Telephone and in-person interviews are more expensive than mail questionnaires, but their response rates are considerably higher than those for mail questionnaires. The total design method combines the best of all survey methods by balancing costs with response rate considerations.

²See D.A. Dillman, *Mail and Telephone Surveys: The Total Design Method*, New York: John Wiley & Sons, 1978, for an in-depth treatment of this survey method.

TABLE 3-1

SURVEY METHODS AND COSTS

Survey method	Response rate %	Average cost \$	
		Per-attempted contact	Per-successful contact
1. Mail questionnaire	40	5	12
2. Telephone interview	60	20	33
3. In-person interview	70	40	57
4. Total design method	65	17	26

Source: Various survey research documents.

Notes: Mail questionnaire costs include clerical and data coding functions. In-person interviews do not include travel/lodging costs. Total design method assumes a mixture of mail questionnaires, telephone calls, and in-person interviews. If NASA has additional internal costs, they should be calculated and considered.

The sample size of the survey affects both its accuracy and cost. Since many of NASA processes involve fewer than 250 industry and internal NASA customers, we suggest that NASA survey all of its customers. However, when the customer base exceeds 250 customers, NASA should take a 50 percent sample. Such sampling rate procedures balance data accuracy considerations against survey costs.³

Survey Conduct

NASA should take a survey biannually to periodically review performance progress and continuously obtain customer feedback. It should also use a 100 percent sampling rate when the customer base is under 250 and 50 percent when more than 250.

NASA should pre-test every survey instrument. We recommend that the working group test the survey instrument by a combination of telephone call and in-person interviews. A five percent pre-test sample should be sufficient. A useful procedure for pretesting is

³A random sample may be taken when the customer base is relatively homogenous. However, when the customer base is diverse, the method of stratified sampling is more appropriate for obtaining the desired data accuracy. See George W. Snedecor and G. Cochran, *Statistical Methods*, The Iowa State University Press, 1989, for a practical discussion of sampling techniques.

to ask respondents a question such as, "Why did you give such a rating in answer to this question?" The answers may indicate that the respondents are interpreting the questions differently from the way the working group had intended.

After the pre-test, an additional 6-week period should be set aside for collecting questionnaire responses. The questionnaires should be mailed out with a stamped, self-addressed return envelope. After the second week, NASA should mail a card thanking respondents who have completed the questionnaire and reminding others that it is looking forward to receiving their responses. After the fourth week, NASA should make any follow-up telephone calls and personal interviews as is necessary to achieve high response rates.

Expert advice is especially important in conducting the survey. The results will be accurate only if based upon a reasonable cross-section of the population. Further, customer interviews--either telephone or face-to-face--could introduce bias into the survey data if not properly conducted. NASA may want to contract for those services.

Survey Analysis

Before analyzing the data, NASA should code the data for entering into a computer.⁴ It should train specific sections of the organization to transfer the survey data into the computer. Entries should be double-checked to ensure accuracy.

The amount of information yielded by customer surveys can be considerable. In general, analysis of survey data should include examination of the responses to every question for each category of respondent. Such information indicates which products/services are meeting customer standards for different categories of NASA customer. Also, examination of the responses to open-ended comment questions, such as why the respondents gave negative answers to some questions, may suggest process improvements. Finally, more sophisticated statistical approaches may be used for determining the relationship between the responses to various questions, thereby improving understanding of customer thinking.

⁴The survey analysis should be conducted with a common statistical package to facilitate analytical work and comparisons. We have designated the Statistical Analysis System (SAS) for this purpose.

The requirements of Executive Order 12862 dictate that the analysis of the survey specifically include at least the following:

(a) A determination of customer standards for every quality dimension of NASA's products/services. These standards should be summarized from the quantitative answers provided by the survey respondents.

(b) An analysis of the extent to which customers are satisfied with the quality of NASA's products/services. Customer satisfaction scores can be aggregated from the individual customer scores provided by the respondents.

(c) An evaluation of quality gaps between NASA's products/services and the customer's expectations. A summary of the delivery-expectation quality gaps can be obtained from the quantitative scores provided by the survey respondents.

(d) A summary of the relative importance that customers attach to each quality dimension of NASA's products/services. Relative importance can be derived by comparing the customer's importance scores on the quality factors with the total of all customer quality-importance scores.

(e) An assessment of NASA's overall quality performance. Such an assessment should be based upon the construction of the quality index, which is derivable from steps (a) through (d) above. The quality index would provide NASA with an estimate of the percentage of customer standards that it is now satisfying.

(f) An implementation plan that prioritizes the areas most in need of improvement. The quality index can be used to show the effect that closing each delivery-expectation gap would have on NASA's overall quality performance. The customer's concerns with expenditures also should be compared with quality-improvement possibilities. In this way, NASA can target the most fruitful avenues for process improvement and performance enhancement.

Customer surveys may initially be difficult to plan, conduct, and analyze. However, survey work becomes easier as procedures and practices become more routine. It is difficult to develop a useful and unbiased customer survey instrument for the first time. It is also difficult to conduct a survey properly in order to obtain reasonably high response rates. Finally, it is difficult to devise a structure for undertaking comprehensive survey analyses. As the SEUs continuously use this guidance, customer surveys will become less difficult.

4. PERFORMANCE MEASUREMENT SYSTEM

In this section, we define a performance measurement system that addresses all of NASA's immediate and long-term performance initiatives--Executive Order 12862, continual improvement, and the Performance and Results Act of 1993. We then demonstrate that system by applying it to a wind-tunnel case study.

MEASUREMENT FRAMEWORK

A performance measurement system must provide comprehensive signals for an organization to improve performance. A comprehensive performance measurement system has three essential components: the ability to enhance quality, to raise output capability, and to lower costs. Failure to address any of these concerns will always result in performance shortfalls. If an organization focuses largely on quality, it may very well enhance quality but its output and costs could suffer. (Mercedes Benz could be a good example of an organization that focused too much on quality and not enough on other factors). Alternatively, if an organization focuses mostly on output, it may very well raise output capability, but its quality and costs could suffer. (The American car industry in the early 1980s may be a good example of this type of focus.) Finally, if an organization focuses largely on reducing costs, it may very well become more efficient but its output and quality might suffer (e.g., the Yugo). Only when an organization focuses simultaneously on quality, output, and cost can it truly establish a high level of overall performance and customer satisfaction.

We use the concept of performance unit cost to ensure that organizations focus on all aspects of performance simultaneously. Performance unit cost is defined as costs relative to outputs at defined quality levels. Figure 4-1 illustrates the process for integrating costs, output, and quality.

Performance unit cost incorporates the best features of Federal, state, and local government budgeting efforts. Measures of efficiency (cost per unit of output) have been used extensively in the Federal government, especially within the Department of Defense. At state and local governments, measures of effectiveness or outcome (output adjusted for quality differences) also have been used extensively. More recently, state and local governments have combined effectiveness and efficiency measures into performance unit cost or cost per unit of outcome. The Governmental Accounting Standards Board recently has endorsed this approach.⁵

⁵ *Proposed Statement of the Government Accounting Standards Board on Concepts Related to Service Efforts and Accomplishing Reporting*, Governmental Accounting Standards Board, September 15, 1993.

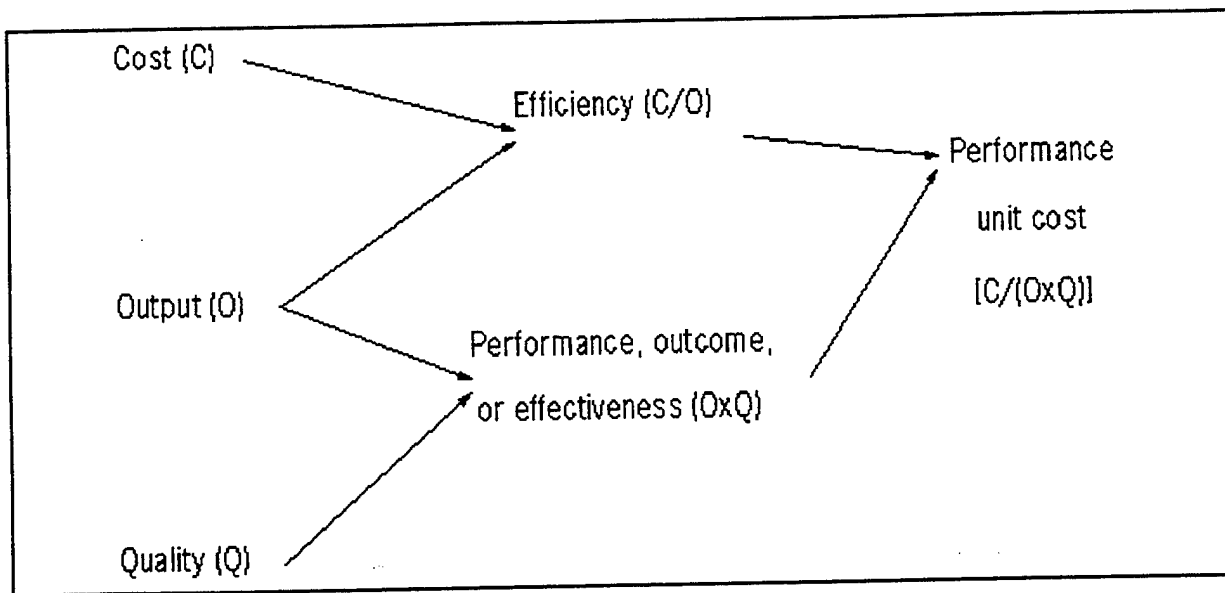


FIGURE 4-1. MEASUREMENT INTEGRATION PROCESS

We now define the elements of performance unit cost. First, we discuss the concepts of cost, output, and quality. Then we discuss the integration of those concepts into a performance unit and performance unit cost.

Cost

Ideally, process costs should be inclusive of operating outlays; appropriate allocations of general, administrative, and other fixed costs; and depreciation charges for use of capital items (such as buildings, facilities, and structures). However, many government cost accounting systems cannot support this concept of costs without substantial upgrades. Some of the problems with cost accounting systems include the following: they cannot readily track variable costs to specific processes, they do not include procedures for depreciating capital items, and they lack the capability to allocate fixed costs to processes. Recognizing such potential difficulties, the Performance and Results Act of 1993 does not require full implementation of sophisticated cost accounting and performance budgeting until the year 2000. Also, industry benchmarking and continual improvement require such cost accounting systems to be most effective. NASA should ensure that its cost accounting and budgeting systems are sufficient for meeting these performance initiatives.

Output

Some NASA processes may produce homogeneous products/services, but most are likely to produce diverse products/services. The measurement of homogeneous outputs is straightforward--simply add the number of units produced (e.g., service hours) during a given time period. But, the measurement of diverse products/services is more difficult and requires the use of indexes.

Table 4-1 illustrates the construction of output indices when the process yields three different kinds of services. Suppose the different services are $S(1)$, $S(2)$, and $S(3)$. Each could be measured in terms of hours used, but, because they contribute differently to the total process output, they must be weighted to take account of the differences. The weights, denoted by $w(i)$, might be relative expenditures or revenues and are fixed over time and sum to unity. The contribution of each service to the total output is its service level multiplied by its respective weight [e.g., $S(1) \times w(1)$], and the summation of all service contributions provides an indication of total output.

Table 4-1

CONSTRUCTING OUTPUT INDICES

Output service (S)	Importance weight (w)	Index contribution (Sxw)
S(1)	w(1)	$S(1) \times w(1)$
S(2)	w(2)	$S(2) \times w(2)$
S(3)	w(3)	$S(3) \times w(3)$
Total	1.0	Index value

Quality

We now need to define quality factors for NASA's products/services and to express NASA's outputs in quality-equivalent terms. NASA's products and services normally are expected to involve multiple quality factors -- such as suitability, reliability, and usability -- so the same basic index approach used to summarize outputs also has application to the summation of quality. However, two major differences in constructing quality indexes exist.

First, unlike the output index, the weights are derived from customer satisfaction surveys (as required by Executive Order 12862) and not from NASA's revenue or expenditure data. In the survey, customers would rate the importance of each quality factor, and those ratings would be used to construct the quality weights in the index.

Second, the performance of quality factor is measured in percentage terms — rather than in actual values as in the case of output measurement — to determine how the actual quality levels compare to customer standards. Moreover, industry benchmarking could also be used as standards in the quality index, but they would have to be as least as high as the customer's standards. We believe, however, that benchmarking should be used only after using customer standards for a period of time.

Equation 4-1 shows the general form of the quality index with "n" quality factors:

$$\begin{aligned}
 QI = & w(1) \times [\text{actual quality}(1) / \text{standard quality}(1)] + [\text{Eq.4-1}] \\
 & w(2) \times [\text{actual quality}(2) / \text{standard quality}(2)] + \dots + \\
 & w(n) \times [\text{actual quality}(n) / \text{standard quality}(n)]
 \end{aligned}$$

The quality index then measures the degree to which the quality standards are met. For example, an 80 percent quality index score would mean that, on the average, the process is achieving 80 percent of the quality standards desired by the customers. The maximum quality index score is 100 percent and the minimum is 0 percent.

Equation 4-1 is also a useful tool for determining the quality factors that have the greatest need for improvement. If two quality factors achieve only 50 percent of their standard levels, for example, then the one with the greater customer weight should receive the higher priority for making improvements. In contrast, a quality factor with a 90 percent achievement level relative to its standard (and a relatively low customer weight) should receive a lower priority for implementing improvements.

Performance Unit

Performance units are outputs standardized at perfect quality levels. Such standardization is needed to measure performance accurately and to encourage high-quality performance. Table 4-2 illustrates three different cases. Case "a" shows that 1,200 units of output were produced at an average of 50 percent of the standards. Its performance units totaled 600 ($1,200 \times 0.50$). In case "b," performance is higher, at 960 units ($1,200 \times 0.80$), reflecting a higher level of quality. Case "c" shows the lowest number of performance units, 560 ($1,400 \times 0.40$), because of a significantly lower quality level. These three cases illustrate that accurate performance measurement must standardize for quality differences, and that organizations could perform poorly if they do not embrace such comprehensive measures.

Table 4-2

Performance Units

Case	Output (O)	Quality index (QI)	Performance unit (OxQI)
a	1,200	0.50	600
b	1,200	0.80	960
c	1,400	0.40	560

Performance Unit Cost

The starting point for defining performance unit cost is to establish the relationship between total costs, on the one hand, and output and quality, on the other. Economists call such a relationship a "total cost function"; its properties can be derived by either regression analysis or engineering value analysis. Skilled professionals would be needed to undertake such technical analyses.⁶ Equation 4-2 represents a total cost function.

$$\text{Total Cost} = f(\text{output, quality}) \quad [\text{Eq.4-2}]$$

It indicates that costs vary with both output and quality, and that such a relationship could be either linear or nonlinear, depending upon the particular circumstances.

Performance unit cost (or PUC) simply expresses the total cost relative to performance units. Dividing both sides of Equation 4-2 by the performance units (output x quality), we can calculate PUC, as Equation 4-3 shows:

$$\text{PUC} = f(\text{output, quality}) / \text{performance units} \quad [\text{Eq.4-3}]$$

Note that PUC is not a constant but varies with output and quality. Many budgeting systems assume that PUC is constant. Such an assumption, however, could lead to incorrect managerial decisions, especially when related to consolidations and

⁶ See Jan Kmenta, *Elements of Econometrics*, New York: Macmillan Publishing Co., Inc., 1971, for a good treatment of regression analysis. Also, see David K. Burt, et al., *Zero Base Pricing: Achieving World Class Competitiveness Through Reduced All-in Costs*, Chicago: Probus Publishing Company, 1990, for a thorough explanation of engineering value analysis.

realignments. Organizations should use a constant PUC only as a very crude first approximation.

Figure 4-2 shows the PUC for a process in which the total cost function is linear. In this situation, average variable costs and marginal costs are constant. Thus, PUC falls as fixed costs are spread over more and more performance units (such as at point "b"), and it approaches a constant (the marginal cost) as the number of performance units become large (such as at point "a").⁷

The PUC curve can be used for various managerial purposes. For instance, it could be used to summarize organizational progress for making improvements. Suppose an organization initially operates at point "b," signifying a relatively high PUC. That organization might pursue cost reduction and/or quality initiatives to improve its performance. If it simply reduces its costs for that level of performance units (such as at point "c"), then its PUC would decline from PUC(b) to PUC(c). If it focuses on quality enhancement (such as at point "a"), then its PUC also would decline, but less significantly--from PUC(b) to PUC(a). Either enhancing quality or reducing costs may be appropriate, depending upon customer feedback.

The PUC curve could also be used to target improvement initiatives. If customers indicate that costs are the primary problem, then an organization's strategy might be to undertake cost reduction efforts (such as plans to move from point "b" to "c" in Figure 4-2). If customers, however, indicate that quality is their major problem, then the appropriate strategy might be to undertake quality improvement efforts (such as plans to move from point "b" to "a").

Finally, the PUC curve could be used to develop budgets. As an example, the budget required to operate at performance units of UP(a) would be $PUC(a) \times UP(a)$; or, the budget to operate at UP(b) performance units would be $PUC(c) \times UP(b)$ after cost-reduction efforts.

⁷ An example of a linear cost function might be as follows: Total cost = $a + b (\text{Output} \times \text{Quality Index})$. In this situation, marginal cost is equal to "b" and is constant. $PUC = a / (\text{Output} \times \text{Quality Index}) + b$, with the first term reflecting average fixed costs (which vary inversely with output and quality) and the last term reflecting the constant average variable or marginal costs.

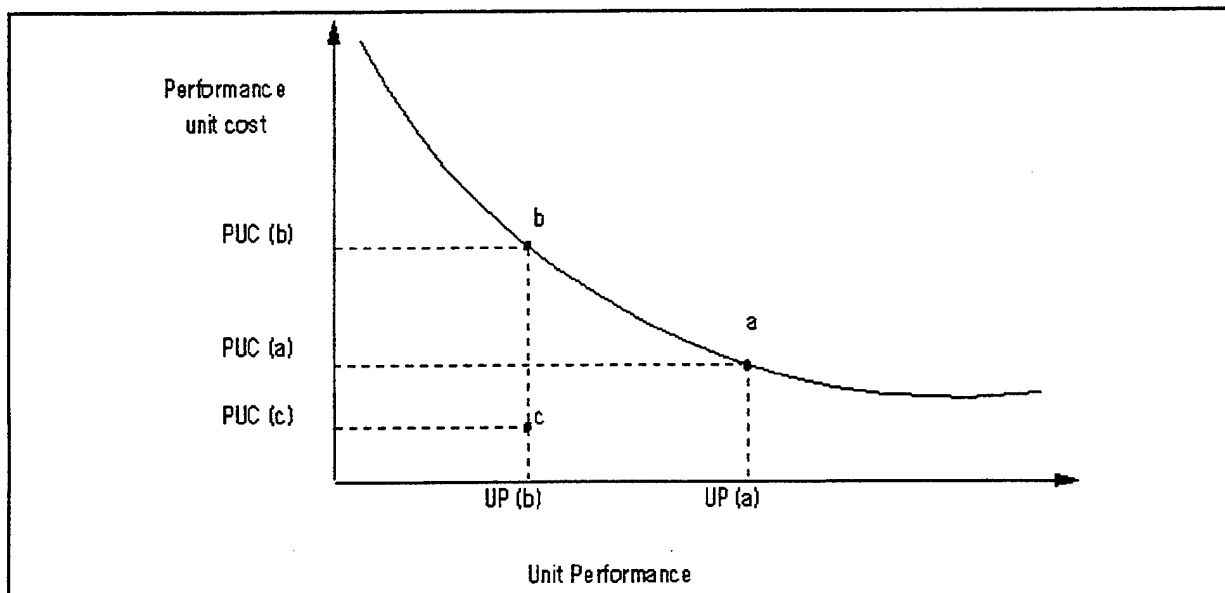


FIGURE 4-2. EFFECT OF LINEAR COST FUNCTION ON PUC

WIND-TUNNEL CASE

Using our definition of processes, the Ames Research Center (ARC) wind-tunnel operations could be classified as a single process for measuring performance and making improvements. It is our understanding that ARC operates three different types of wind tunnels: a 7-by-10-foot high-speed tunnel; a 40-by-80-foot moderate-speed tunnel; and an 80-by-120 foot low-speed tunnel. Each of those tunnels supports different customers. Also, ARC schedules wind-tunnel usage in order to minimize power, maintenance, and repair costs. Finally, the ARC wind tunnels further support NASA's own operations (e.g., in flight orbiter preparations) and industry (e.g., in helicopter research).

In illustrating our performance measurement system with the ARC wind-tunnel operation as a single process, we need to first define and formulate the elements of performance units for the single wind-tunnel process: cost, output, and quality. Then, we need to formulate the total cost and PUC curve, as well as illustrate their application to management.

Cost

The total costs (TC) for ARC's wind-tunnel process may be broken down into two components: operating costs and depreciation charges. Operating costs (OC) consist of power, maintenance, repairs, and other variable costs, as well as some administrative and fixed costs that are associated with the wind-tunnel operation. Depreciation charges (DC) reflect the amortization of expenditures

for the wind-tunnel facilities, equipment, and other capital items. Equation 4-4 shows the straightforward calculation of TC, in constant dollars. It reflects the real resources necessary to provide wind-tunnel services at certain levels of quality.

$$TC=OC+DC \quad [Eq. 4-4]$$

Output

The wind-tunnel outputs consist of low-, medium-, and high-speed wind-tunnel services. Each of those service outputs could be measured in terms of usage hours--low-(l), medium-(m), or high-(h) speed hours. In order to combine these outputs into a composite, we need to weight them to reflect their relative contributions to the total ARC wind-tunnel service. We believe that relative cost weights would best serve this purpose. Equation 4-5 shows the calculation of the output index (OI) for the ARC wind tunnel process.

$$OI = w(1) \times l + w(2) \times m + w(3) \times h \quad [Eq. 4-5]$$

Quality

The wind-tunnel services are very likely to vary in quality in a number of respects. We have chosen three quality dimensions to illustrate this point: suitability, usability, and reliability. Suitability relates to the adequacy of the ARC wind tunnels offered for meeting the testing requirements of its customers. Usability refers to whether the wind-tunnel service schedules are reasonable for meeting the needs of both NASA and industry customers. Reliability indicates whether the wind tunnel operation performs well and without interruption. Each of these quality dimensions is expressed as a percentage of actual performance as compared to the standard measures. We then need to combine these quality measures into an overall quality index (QI) using Equation 4-6.

$$QI=i(1) \times (\%suit.) + i(2) \times (\%use.) + i(3) \times (\%rel.) \quad [Eq.4-6]$$

The quality factor weights in the index—i(1), i(2), and i(3)—should reflect the relative importance that industry and NASA customers attach to them. A customer survey could use a 1-to-7 scoring system (see Section 3) to determine customer standards and satisfaction for meeting those standards.

Performance Unit Cost

To obtain performance unit cost for the ARC wind-tunnel process, we need to follow three sequential steps:

(a) Define unit of performance (UP) using the formula $UP = OI \times QI$, where OI is computed using Equation 4-5 and QI using Equation 4-6.

(b) Establish the relationship between total cost and the quality and output indices. Both linear and non-linear relationships should be considered; they can be established by using either regression analysis or engineering value analysis.

(c) Calculate performance unit cost by dividing the UP measure from (a) into the cost equation established in (b).

Management Uses

With the quality index, ARC can then determine where it needs to make improvements by expressing the quality index (Equation 4-6) in change or complete difference form as in Equation 4-7:

$$d(QI) = i(1) \times d(\%suit)gap + i(2) \times d(\%use)gap + i(3) \times d(\%rel)gap$$

[Eq.4-7]

The gap for each quality factor indicates the remaining difference between the customer's standard and actual satisfaction level. For example, if a customer indicates that 60 percent of the standard level is met for suitability, the remaining actual-standard gap is 40 percent. If the weight for suitability is 0.60, then improvements in suitability can contribute a maximum of 24 percent to overall wind-tunnel process quality (40 percent gap \times 0.60 weight in quality index). ARC could also determine the relative contributions of the other quality factors to the overall potential improvement in ARC wind-tunnel process quality. Armed with this information, ARC then could prioritize its improvement efforts according to their relative contributions to changes in overall quality.

ARC could use this same performance measurement system for other managerial purposes. Through the customer survey, it could determine the importance of wind-tunnel expenditures to the users and then compare that result to potential quality initiatives. If the customers consider expenditures more important than quality, ARC should focus its process improvements on reducing costs. Finally, ARC's overall progress on wind-tunnel process improvements and budgeting requirements could be derived from the performance unit cost curves shown in Figure 4-2.